A Literature Review on Design of Overhead Monorail Crane for Material Handling

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Abstract— The design of overhead monorail crane is different from general structural design because of its loading conditions and its effects. There is minor axis bending occurs in case of runway beam because of moving load. To design curved runway beam is very challenging due to additional torsional effects. The previous work has been done to evaluate different effects like lateral torsional buckling, moving load effect and deformations of the steel I beams. Behavior of simple curved beam is also studied by some researchers. In this review paper, the previous work will be discussed briefly related to design of monorail runway beam, curved beam and supporting structure.

Key words: Monorail Structure, Curved Runway Beam, Bottom Flange Bending, CMAA 74

I. Introduction

Monorail systems come in a variety of arrangements and load capacity and are used with a number of attachments to handle or lifting of load for conveying to different portions of industry.

Monorails are a continuous run of fixed, overhead runway for lifting, lowering and suspend the load to be transported with the help of trolley hoists. The control of movement or travel of trolley is controlled manually in case of hand propelled system or by electrical or pneumatic system in case of automatic monorail system.

II. Literature review

The general monorail structure design includes the design of runway beam, support positions, design of supporting structure and connections. There are very few works have been done by the previous researchers for the design of whole monorail system.

So, the full system is divided into different individual components, like monorail straight I Beam, Curved I beam and design of supporting Beam and columns. In this review, the research works in the area of monorail system and its components-parts have been presented. This may be helpful to people who are working in this area.

A. Designof Monorail System:

Tomas H Orihuela[3] and A D Anjikar et al.[4]describe the basic procedure of monorail system design. Generally I section beams are used for monorail system having high load capacity. Thestructural design should follow the design criteria given in CMAA 74. The monorail system is checked for the stress developed, deflection and local capacity check. For high speed monorail system, it is also compulsory to check for fatigue.

These works are limited to only straight runway beam design and didn’t explain the structural or curved runway beam design.

A D Anjikar et al.[5]studied the uses of seven different ratio to reduce cost assigned to material handling activities and increase overall plant productivity. They discuss the problems under Design load rating or lift load, Safety, load, or impact factors to use, Path for conveyor, preferred method of support, Maximum lift design load. In this paper the work is not explained with specific industrial application.

B. Design of I Beams:

NenadZrnićet al.[6]gave loading capacity curves of I-beam runway beams according to capacities related to strength of bottom flange and lateral buckling of top flange. They used the “Mendel” recommendation for bottom flange bending and checked with CATIA. Strength of specific I beam depends of beam span (L) and wheel position on I beam (w). The effect of torsional effect due to lateral load is not considered in developing the load capacity curve.

N.S. Trahair[7]analyzed the influence of restraints on elastic lateral buckling (without distortion) of monorails loaded at the bottom flange, and shows how this might be accounted for in strength design. He used finite element lateral buckling program FTBER, which was developed from the finite element computer program PRFELB for the analysis of the elastic flexural-torsional buckling of beam-columns and plane frames. He developed a rational, consistent, and economical strength design method for determining the nominal lateral buckling resistance of a number of monorail beams, cantilevers and overhangs which are loaded at the bottom flange and supported at the top flange.

K. M. Ozdemiret al.[8]analyzed the lateral distortional buckling of overhanging monorails and he concluded that the location of loading and supports is significant factor in buckling of overhanging monorails. The increase in web slenderness leads to decrease in buckling capacity of overhanging Monorail beams.

Again N.S. Trahair[9]analyzed the inelastic buckling of monosymmetric steel I-beams under uniform bending and non-uniform bending is studied and compared with design recommendations. The result is compared with EURO Code Recommendations and Finite Element Computer Program PRFELB. For hot rolled beams in uniform bending, the inelastic buckling resistance increases almost linearly as the slenderness decreases, until strain hardening occurs. Three regimes are significant in the inelastic buckling resistances of hot-rolled monosymmetric beams under moment gradient.

1) For beams for which the maximum moment causes compression in the smaller flange, the resistance is low and increases with moment gradient.
2) For beams for which the maximum moment causes yielding in the larger flange before the minimum end moment causes yielding in the smaller flange, the resistance is high and increases with moment gradient.

3) For beams for which the minimum end moment causes yielding in the smaller flange before the maximum moment causes yielding in the larger flange, the resistance is moderate, and decreases with moment gradient.

IlkerKalkanet al.[10] investigated the effect of web deformations in a lateral distortional bending mode on the buckling moments of doubly-symmetric steel I-beams. Analytical buckling moment expressions applicable to both elastic and inelastic lateral distortional buckling were developed. These expressions account for the reductions in the torsional and warping rigidities of I-beams due to web distortions. The reductions in the buckling moments of doubly-symmetric steel I-beams due to web distortions increase as the slenderness of the web increases. The reduction in the buckling moment of a steel I-beam due to web distortions increases as the unbracedlength of the beam increases.

E. Mardani[11]analyzed the beam under the moving concentrated and distributed continuous loads. The vibration equations of motion are derived from the Hamilton's Principle and Euler–Lagrange Equation. In this study, the amplitude of vibration, circular frequency, bending moment, stress and deflection of the beam has been calculated.The results of this study indicate that when the material of the beam is considered physically nonlinear, there is no critical velocity and the resonance phenomenon doesn’t happen. Analysis shows that the more is the speed of the moving load, the more is the amplitude of the vibration.

C. Design of Curved Beams

The designs of curved beams are very critical part in any design process because of extra torsional and warping effect. There are very few works done by researchers in the past some of which is discussed here.

Yong Lin Pi and N S Trahair[12] studied the inelastic bending and torsion of steel I beam. They considered minor axis bending actions for interaction ratio which gives the better design check for strength of I beams.

Again Yong Lin Pi and M. A. Bradford[13] prepared a finite element model of curved beam for 3D nonlinear inelastic analysis of I beams .they concluded that for curved beams with a large included angle, torsion is major criteria for design.

Y B Yang et. al[14]presented the vibration study of curved beam und moving load. They consider centrifugal effect in addition to other load and give more clear view of dynamic response.Tore Dahlberg[15]addressed the problem of calculating deflection of curved beams. He used Castigliano theorem and numerical integration algorithm from the MATLAB package. He solved the problems of two different cases: statically determinate case and statically indeterminate case.

In the previous work they did not consider the effect of lateral load and bottom flange bending.

The work is not explaining the behavior of curved beam under anyreal engineering applications.

D. Design of Supporting Structures:

RajpandianR[16]designed and analyzed the structure of EOT crane of capacity 50 kN.He used “Indian Standard Code for Steel Design” for theoretical work and ANSYS for analysis of structure. The buckling resistance moment must exceed the factored moments for the gravity loads including impact. The horizontal bending moment is assumed to be taken by the top compression flange only. The overall buckling check is applied. The web of the girder is checked for its shear capacity and buckling. Check for local compression under wheels is also applied. As serviceability requirements, the crane girder is checked for vertical deflection due to static wheelloads, for horizontal surge due to crane surge and for fatigue.

Anwar Badawyet al.[17] investigated the buckling behavior of steel beam-column elements for the sake of developing an analytical model to calculate their ultimate resistance under axial compression and bending moment. An analytical model based on Young's equation and similar to Perry formulation has been developed to predict the ultimate resistance of beam columns undergoing interactive buckling. The model is validated by comparing its results with those obtained by the Finite Element Non-Linear Elasto-Plastic analysis using ANSYS 5.4 program. It has been shown that the developed analytical model accurately predicts the interactive strength compared to the finite element non-linear analysis and to the EC3 design approach.

III. RUNWAY BEAM DESIGN

In practice, the actual load is usually suspended from one or more monorail trolleys and is therefore transmitted to the supporting monorail, at two or more points. Therefore, it is necessary to convert the actual distributed load into an equivalent center load, ECL. The two ends of the runway beam are assumed to be simply supported, in the sense that the flexural displacements and twisting rotation of the beam are restrained at the supports to avoid failure of other system if one part of system fails in any case.After having determined the ECL, a rail of the proper depth and weight may be selected to suit the span and specified deflection limits. It then becomes necessary to calculate the maximum hanger loads necessary for designing or checking the design of, the overhead supporting structure.

IV. CONCLUSION

After following above research paper it is concluded that for the design of monorail system the effect of moving loads must be considered in design. The loading in bottom flange causes local bending stress developed in the I beam. Design of curved beam is followed by considering the additional torsional and warping effect and finds the appropriate support positions to avoid buckling and deformation. Thus whole monorail system designed and checked for strength and rigidity by interaction ratio.

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